MicroRad 2016, Helsinki, Finland

MULTI-SCALE L-BAND BRIGHTNESS TEMPERATURE ANALYSIS FOR SOIL FREEZING AND THAWING PROCESS STUDY

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Surface Freeze/Thaw

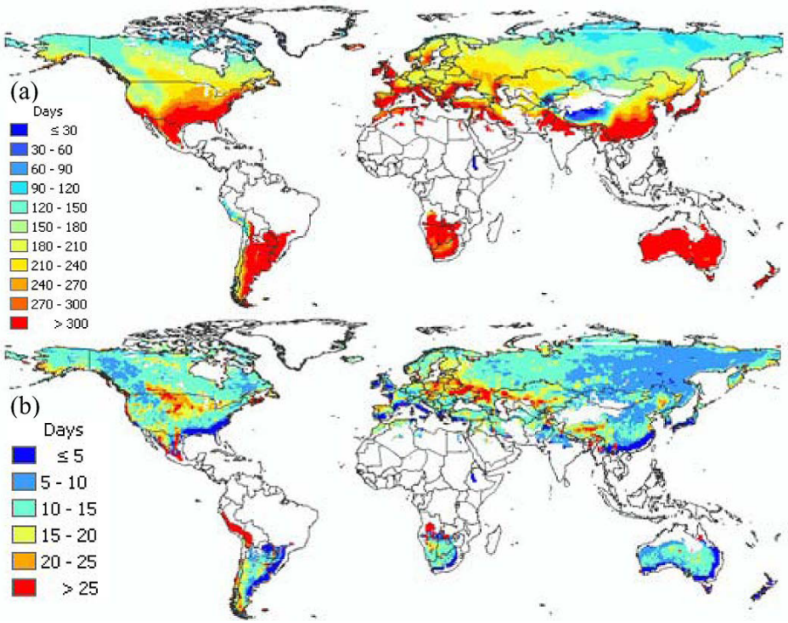
Rational:

* Surface energy balance
* Net carbon fluxes in boreal and sub-arctic regions
* Permafrost monitoring
* Hydrological applications

Over one-third of the global land area undergoes a seasonal transition between predominantly frozen and non-frozen conditions each year. Closely linked to:

- timing and length of the vegetation growing season
- seasonal evolution of land-atmosphere carbon dioxide exchange
- interactions between soil processes and snow melt

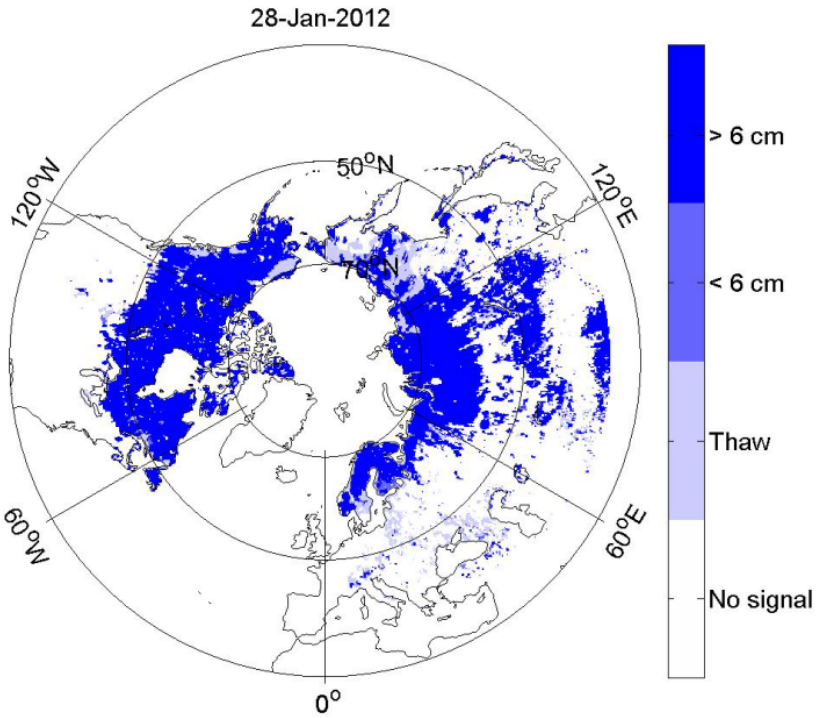
The land surface F/T state acts as a natural on/off switch for hydrological and biospheric processes over northern land areas and at high elevations.



Average non-frozen period (top) and (bottom) standard deviation of the non-frozen period [days yr^{-1}] derived from SSM/I data(1988–2007)

SMOS F/T product

- FT estimates derived from SMOS 1.4 GHz L-band radiometer measurements
- 45 km spatial resolution
- Less sensitive to snow & vegetation; RFI poses a challenge



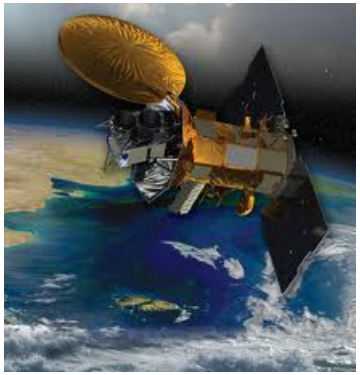
Example FT classification derived from SMOS measurements

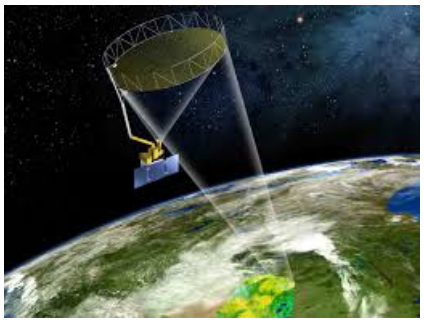
Rautiainen et al., RSE, 2014

REF

L-Band Spaceborne Radiometers

Mission	LRD	Measurement	Instrument Complement	Radiometer Resolution/ Revisit	Incident Angle (°)
SMOS (1)	Nov. 2009 - …	Soil Moisture Ocean Salinity	L-band radiometer	50 km / 3 days	0-65
Aquarius (2)	Aug. 2011 – Jun. 2015	Ocean Salinity Soil Moisture	L-band radiometer, Scatterometer	100 km / 7 days	Beam 1: 29.2 Beam 2: 38.4 Beam 3: 46.3
SMAP (3)	Apr. 2015 - …	Soil Moisture Freeze/Thaw state	L-band radiometer	40 km / 2-3 days	40





(1) SMOS Weekly averaged from daily reconstructed TB (L3TB) (www.catds.fr/sipad/)
(2) Aquarius weekly-polar gridded TB version 3.0 (Brucker et al., *The Cryosphere*, 2014)
(3) SMAP NSIDC : LC1, TB Ease Grid 36 km

Objective #1
SMOS and Aquarius F/T

* Evaluate Normalized Polarization Ratio (NPR)-based F/T detection algorithm
  * SMOS
  * Aquarius

Relative Frost Factor (FFrel)

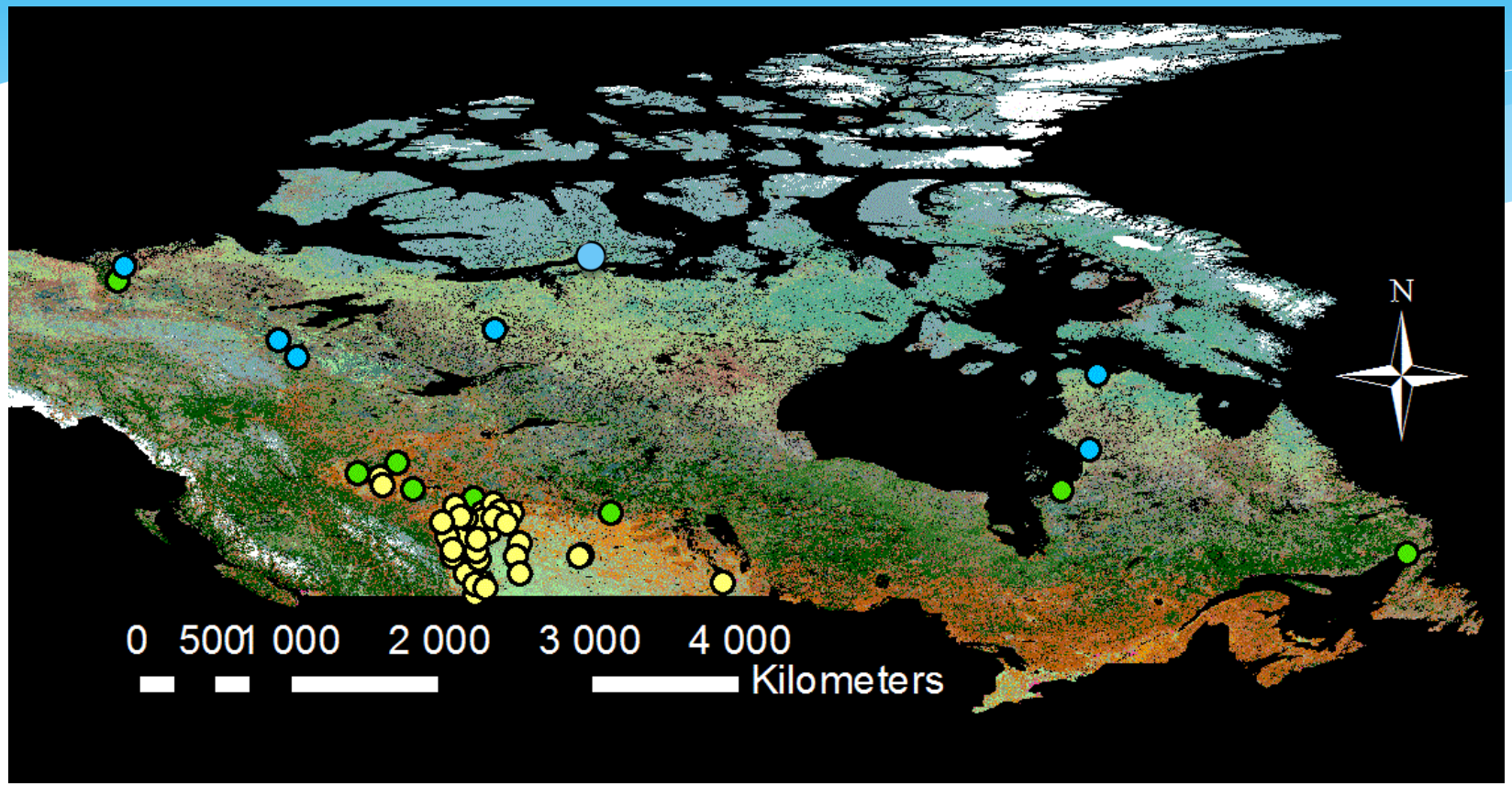
$$NPR = \frac{TB_V - TB_H}{TB_V + TB_H} \Rightarrow FFrel = \frac{NPR(t) - NPR_{fr}}{NPR_{th} - NPR_{fr}}$$

$FFrel < \Delta \rightarrow freeze$ and if $FF(t) > \Delta \rightarrow thaw$

* Evaluate the influence of land cover and sensor configuration (angle) on F/T detection

Roy A., A. Royer, C. Derksen, L. Brucker, A. Langlois, A. Mialon, Y. H. Kerr (2015) Evaluation of Spaceborne L-band radiometer measurements for terrestrial Freeze/Thaw retrievals in Canada, IEEE JSTARS, DOI:10.1109/JSTARS.2015.2476358.

Study Sites



Soil and air temperatures and snow measurements

7 tundra , 8 boreal forest and 35 prairie sites

Ancillary Data

* Surface temperature : weekly binary (F/T) datasets
  * In situ soil temperature (2 to 5 cm)
  * In situ air temperature
  * Cloud free MODIS land surface temperature ($MODIS_{LST}$)

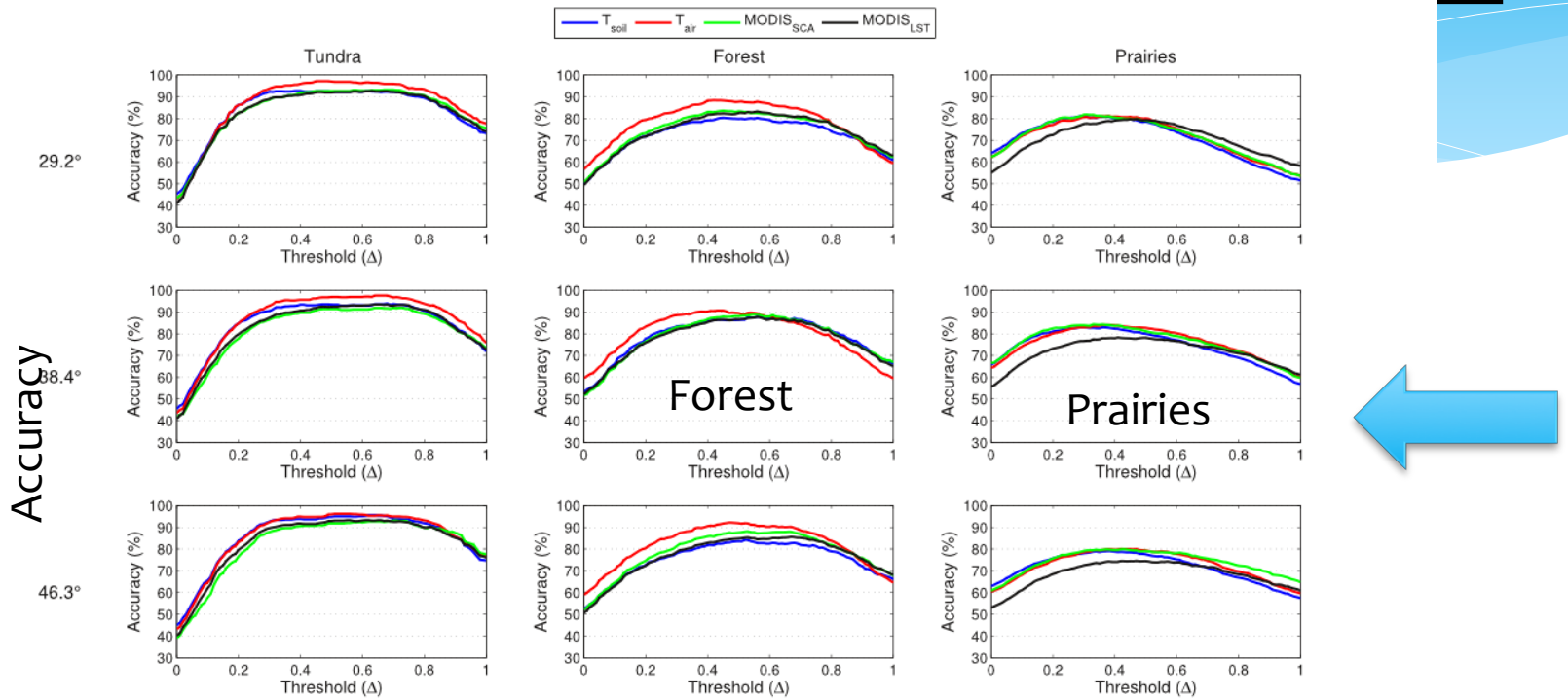
if majority of X -< 0 = frozen week

* Cloud free MODIS snow cover area ($MODIS_{SCA}$)

if majority of SCA>10% = frozen week

Objective 1 : Results

Threshold (Δ) evaluation with **Aquarius**



Accuracy = # correct predictions / total weeks(%)

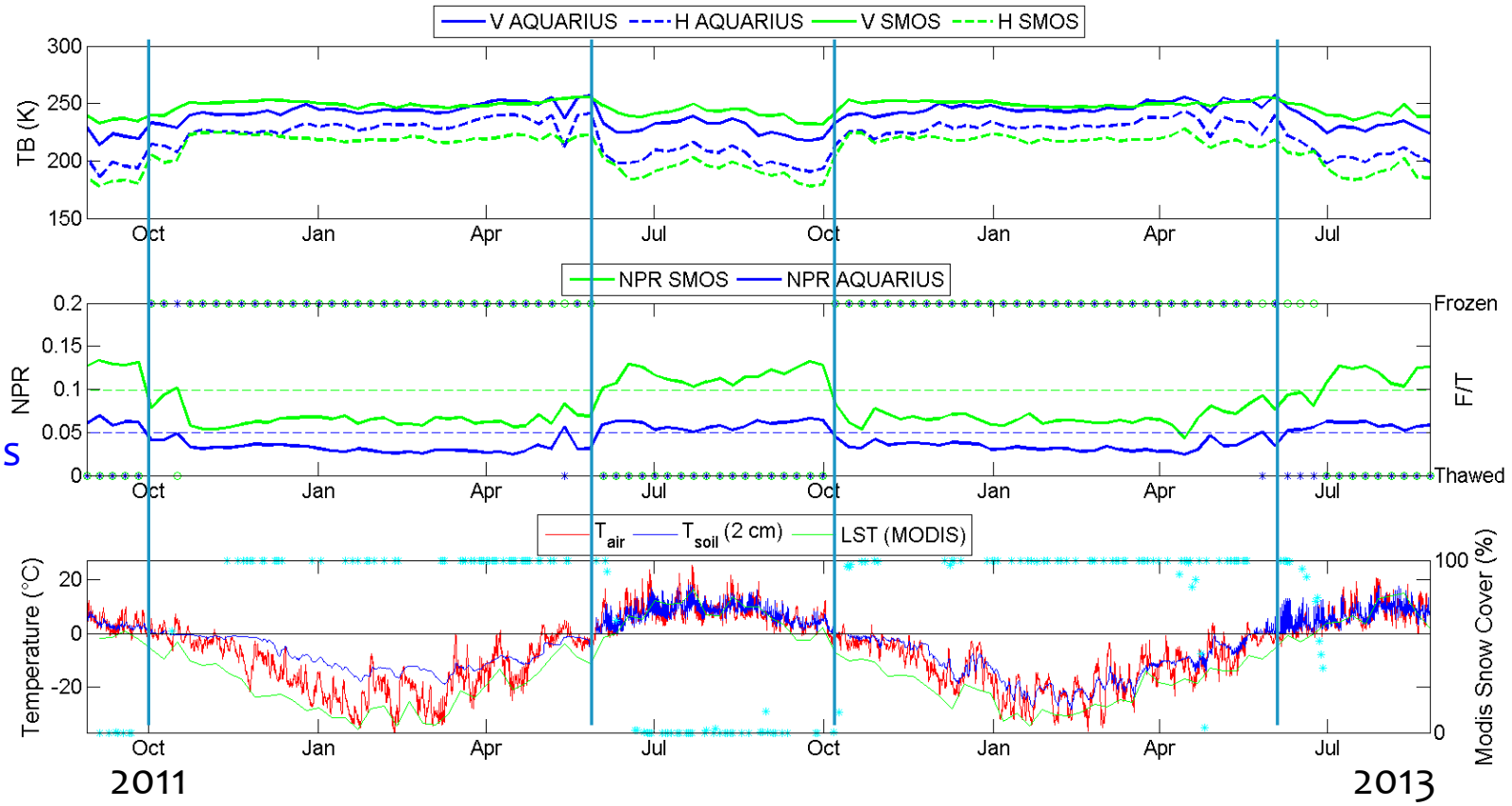
- *Best Accuracies with T_{air}*
- *Best accuracies over Tundra and worst over Prairies*
- *Tundra : broad range in the treshold (0.3 to 0.7)*
- *Optimized treshold at 38.4°: forest = 0.46; Prairies = 0.39*
- *For SMOS: best Accuracies with higher incidence angle (60°) → larger V-H at Brewster*

Objective 1 : Results

Tundra temporal series (Salluit) SMOS & Aquarius

SMOS

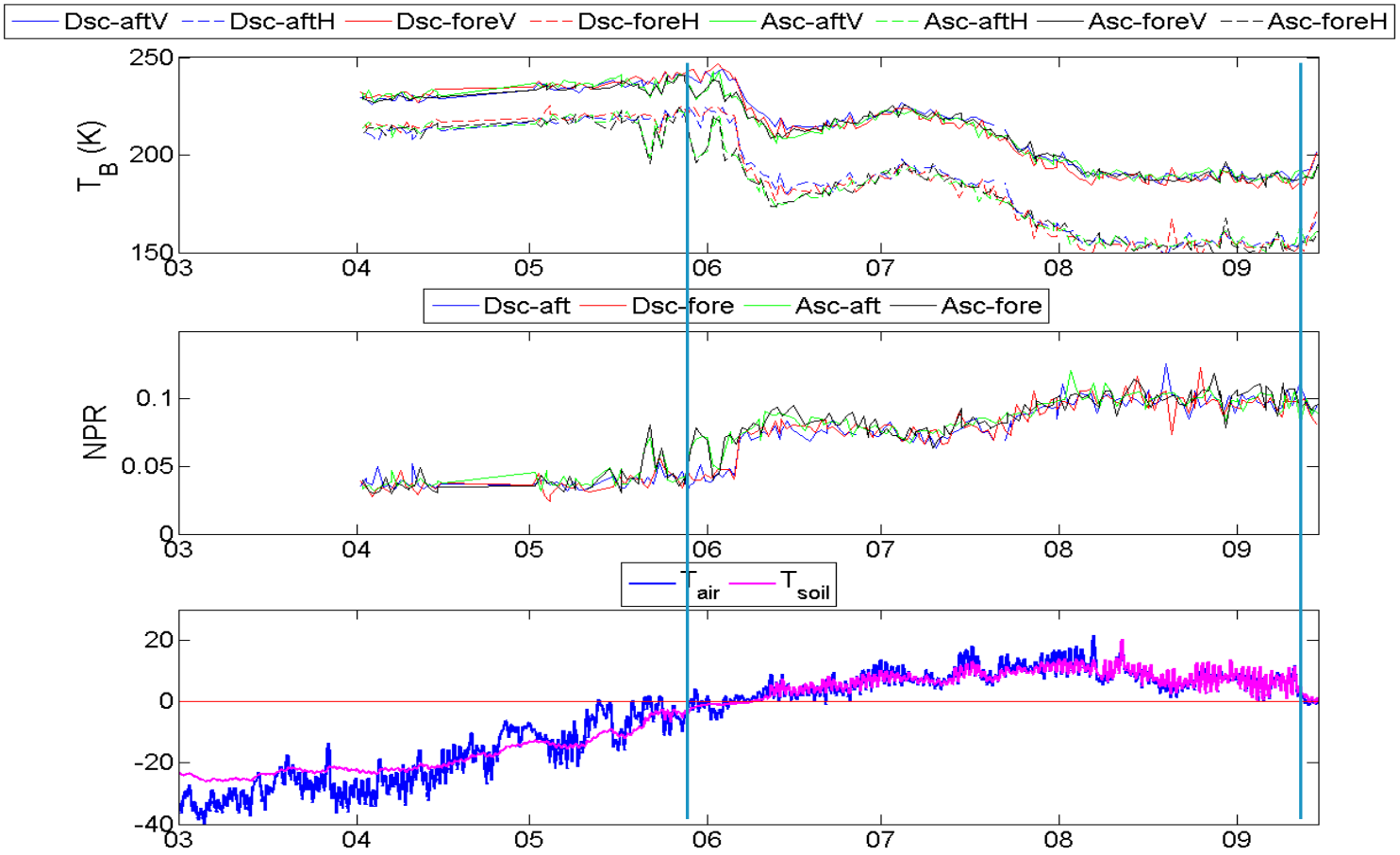
Aquarius



- Clear NPR F/T signal in tundra
- SMOS at 55-60° and Aquarius at 38.9°

Objective 1 : Results

Tundra temporal series (Cambridge Bay) SMAP F/T

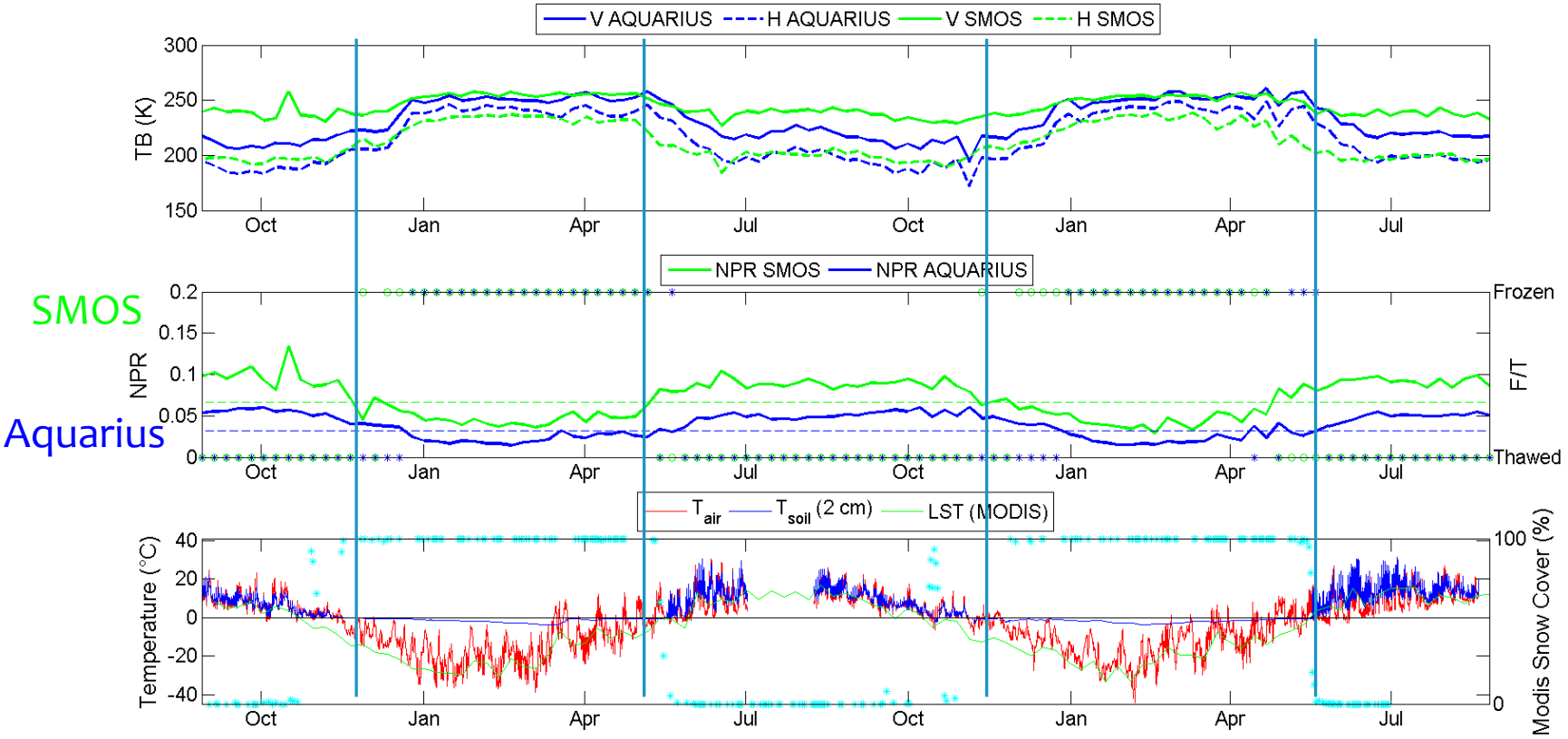


- Latitude = 69.13 N
- Good F/T signal
- Influence of lakes (TB drop in July)

SMAP NSIDC : LC1, TB Ease Grid 36 km

Objective 1 : Results

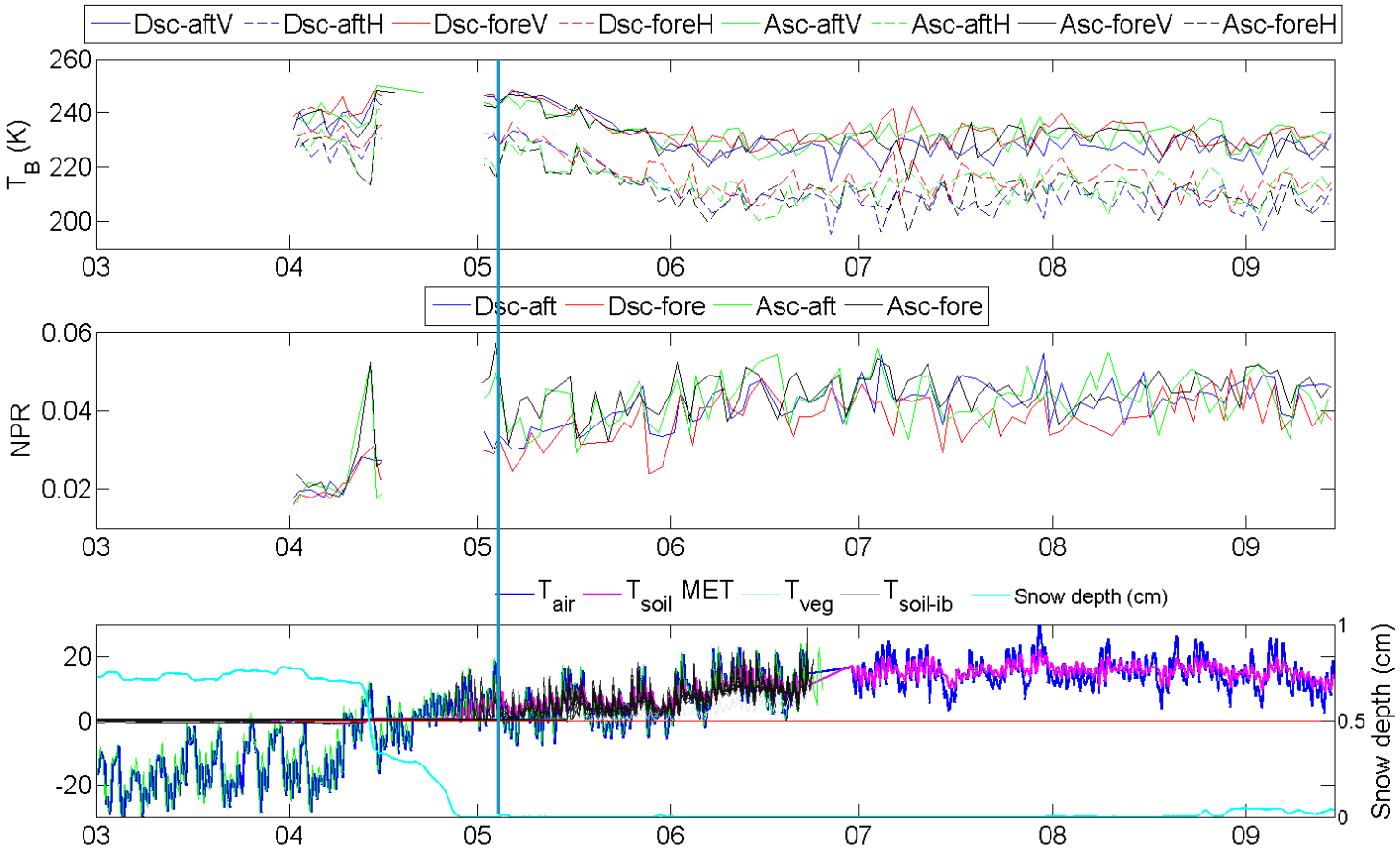
Boreal Forest temporal series (Kuujjuarapik)



- Smoother F/T transition (vegetation soil continuum)
- SMOS at 55-60° and Aquarius at 38.9°

Objective 1 : Results

Boreal Forest temporal series (Baie-James) SMAP F/T

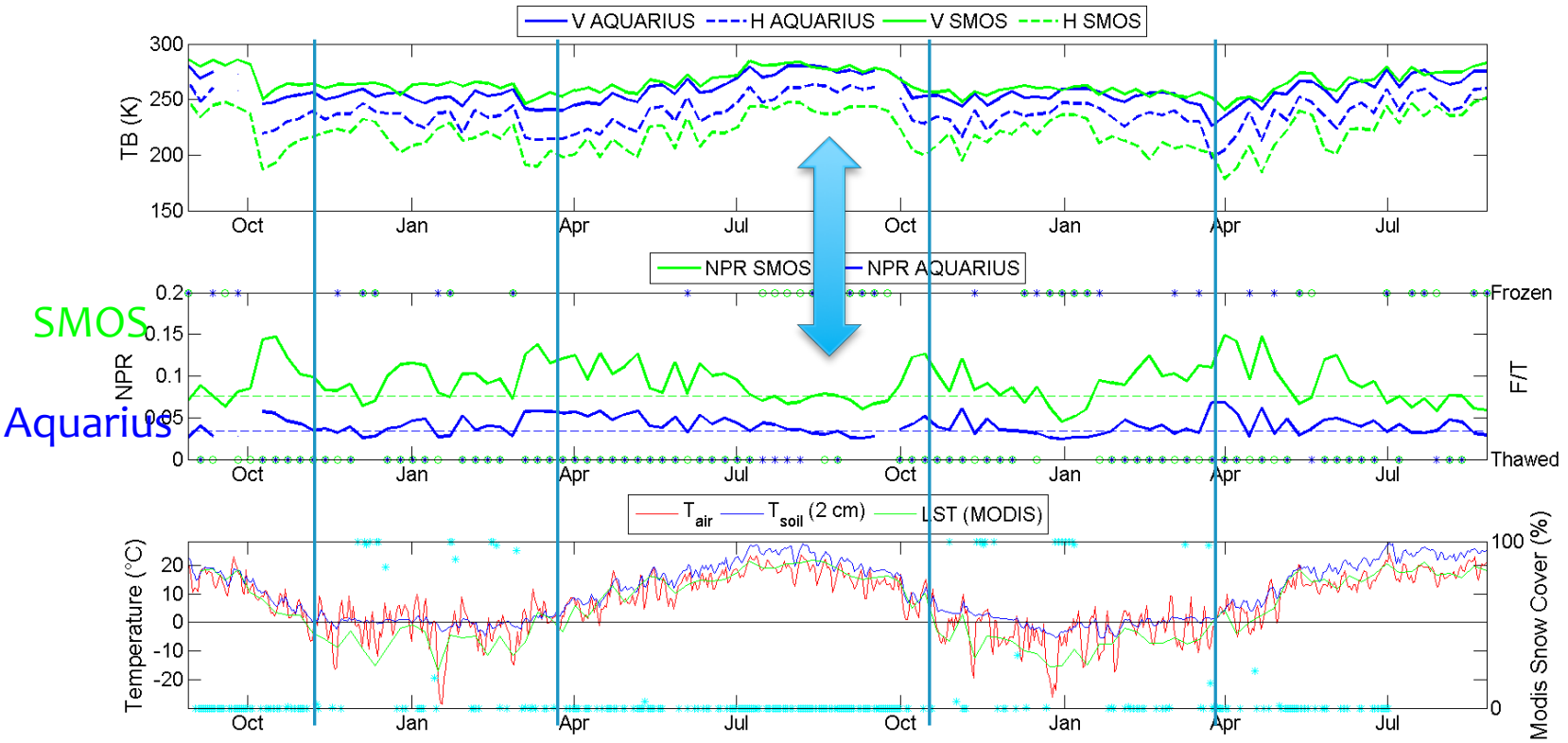


- Soil barely frozen (even with T_{air} < -40°C)
- More thaw with Asc passes / more freeze with Dsc passes
- Clear signal with the presence of snow
- Differences between fore- and aft-look

SMAP NSIDC : LC1, TB Ease Grid 36 km

Objective 1 : Results

Prairies temporal series (Alberta)



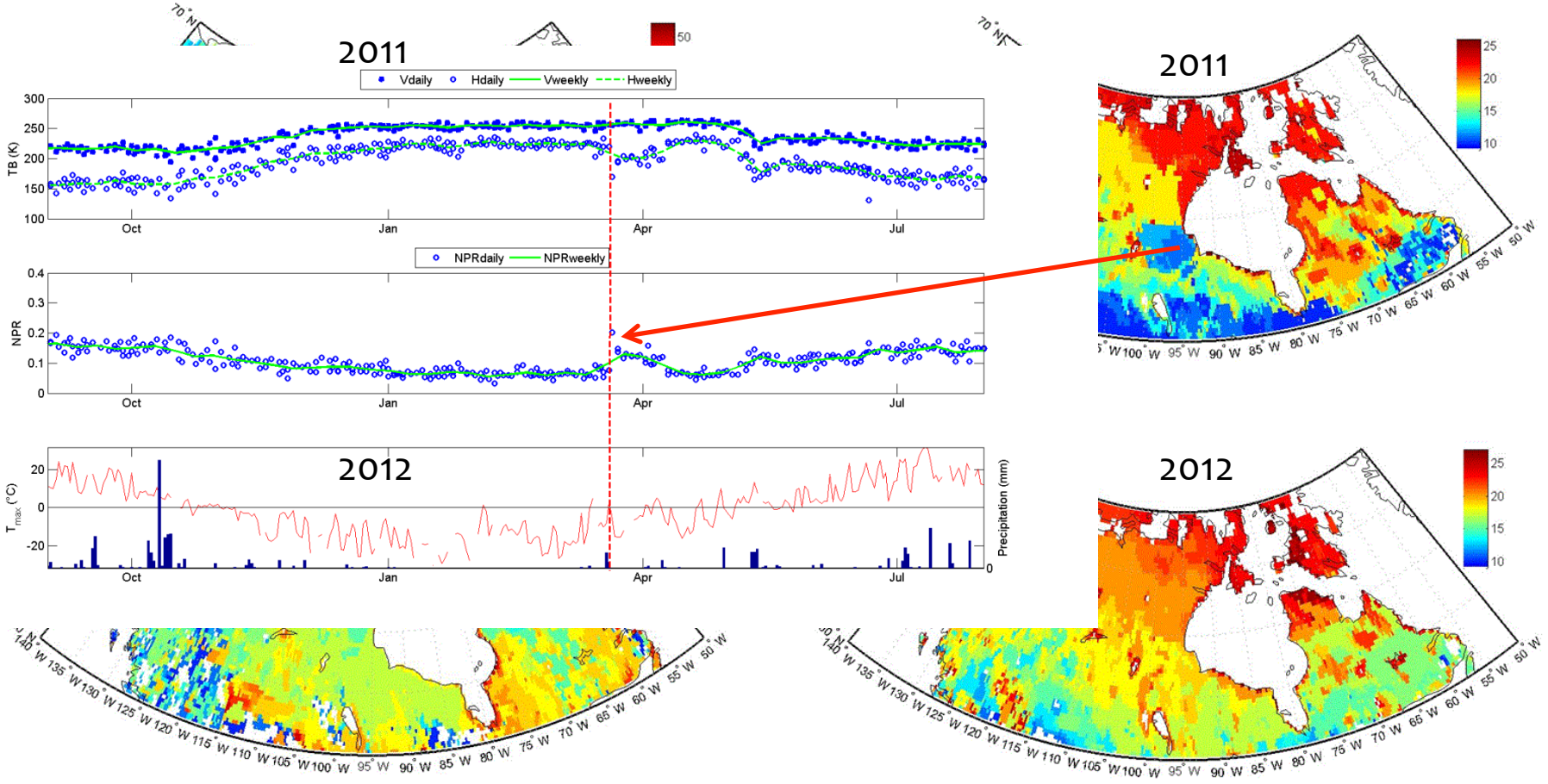
- F/T signal is less clear
- TB increase during summers → seasonal crop growth cycle
- Many melt events in winter
- SMOS at 55-60° and Aquarius at 38.9°

Objective 2 : Spatial variability

Freeze onset and Freeze ends maps (SMOS)

Freeze onset in weeks (Fall)

Freeze end in weeks (Spring)

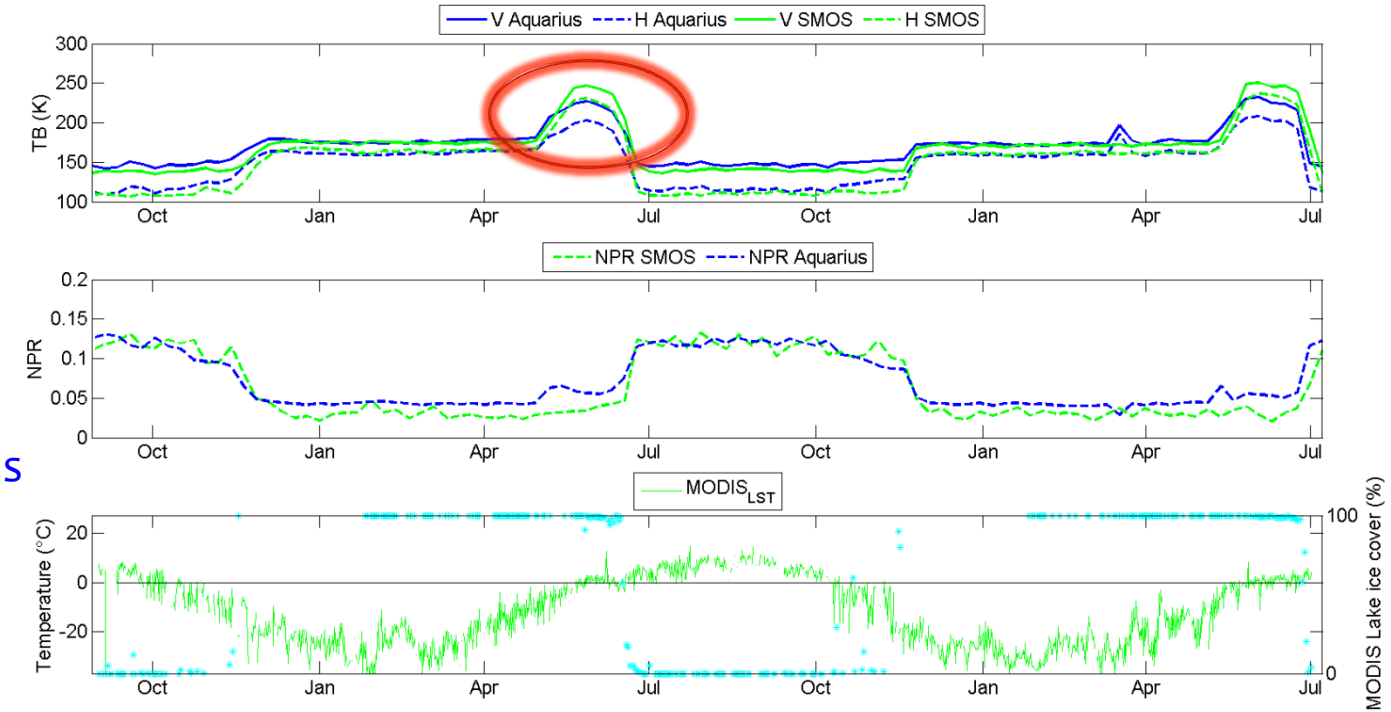


Objective 2 : Spatial variability

Snowmelt effect (Great Bear Lake)

SMOS

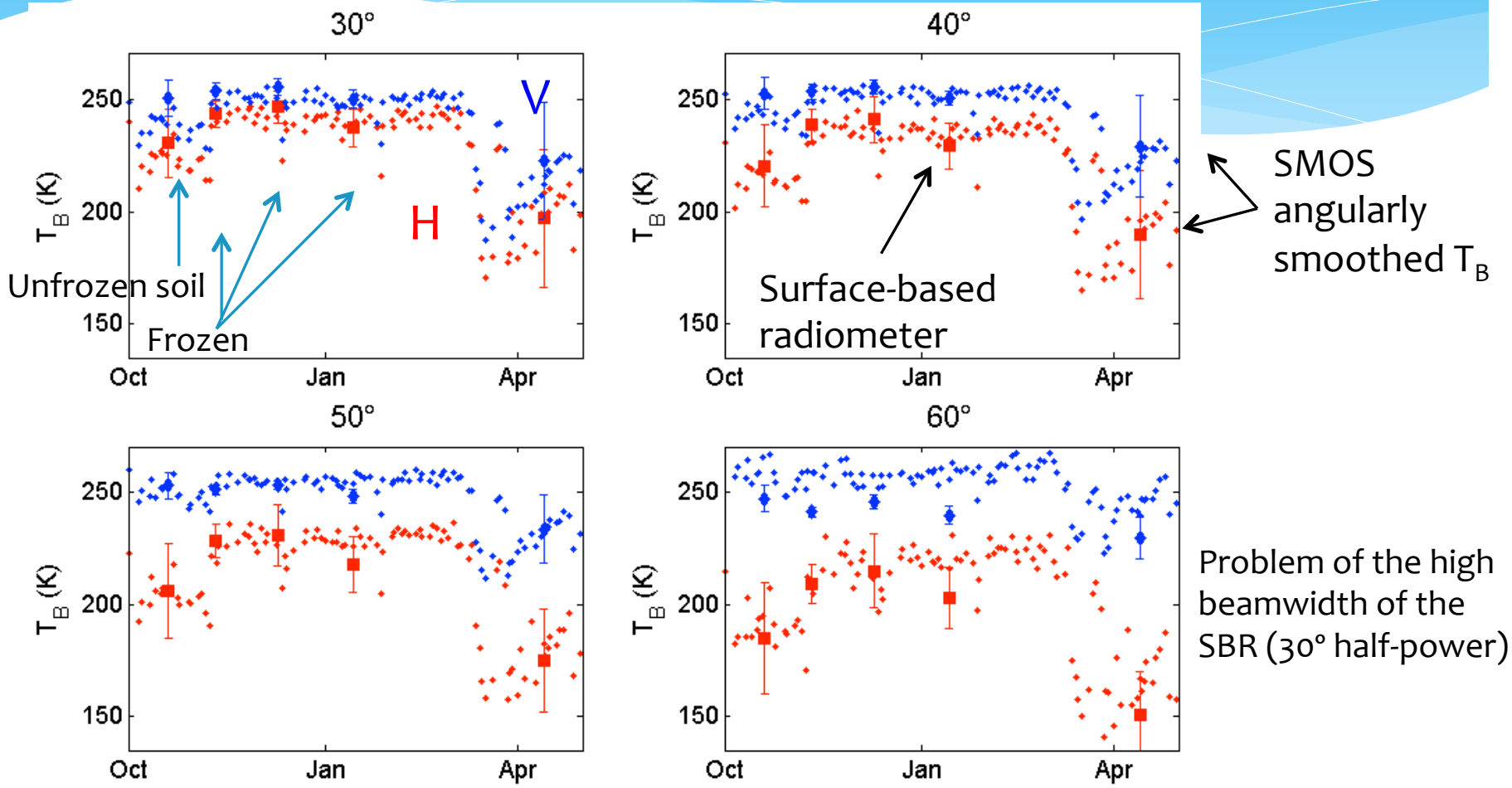
Aquarius



- Pure lake pixel (Great Bear Lake)
- High NPR and low TB in summer (water)
- Low NPR and higher TB in winter (ice)
- Higher TB during spring snowmelt (wet snow)

Objective 2 : Spatial variability

Surface-based vs SMOS T_B (Prairies)



Mean surface-based radiometer T_B and standard deviation for 7 sites over the Kenaston region, Prairies within the same SMOS pixel (2 bare soil, 1 grass, 1 pasture, 3 crop stubble)

Conclusion

* L-band NPR is sensitive to F/T
* But do not use the full potential of SMOS (weekly vs 3 days TB and version 243)
* Applications for SMOP in progress…

Overall accuracy for F/T detection :
90,8% Aquarius
87,8% SMOS

* Better correlation with T_{air} (with the limitation of point measurements)
  - Snowmelt signal in spring
  - Soil temperature (2 to 5 cm) = delay
  - Sensitive to surface freezing
* Vegetation-soil continuum signal in boreal forest
* Need a better understanding/decoupling of FT signal in boreal forest (vegetation phenology vs soil FT)

* Interesting spatial pattern of F/T variability (Rain-On-Snow events)
* Good agreement between SBR and SMOS TB, excepted at 60°

Thanks to *In situ* data providers

* Centre d'Études Nordiques (CEN)
* Alan Barr and University of Saskatchewan (BERMS)
* University of Guelf
* Sharon Smith (Natural Resources Canada)
* Phil Marsh (Trail Valley)
* Peter Lafleur (Daring Lake)
* Agriculture and Agri-Food Canada (AAFC)
* Agriculture Alberta (ACIS)

And Spatial Agencies : ESA, CNES, NASA, CSA

Thanks for your attention